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UNDERSTANDING IT VALUE: A MULTILEVEL, COMPLEX, AND ADAPTIVE SYSTEM PERSPECTIVE

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Abstract

One remaining difficulty in the Information Technology (IT) business value evaluation domain is the direct linkage between IT value and the underlying determinants of IT value or surrogates of IT value. This paper proposes a research that examines the interacting effects of the determinants of IT value, and their influences on IT value. The overarching research question is how those determinants interact with each other and affect the IT value at organizational value. To achieve this, this research embraces a multilevel, complex, and adaptive system view, where the IT value emerges from the interacting of underlying determinants. This research is theoretically grounded on three organizational theories – multilevel theory, complex adaptive systems theory, and adaptive structuration theory. By integrating those theoretical paradigms, this research proposes a conceptual model that focuses on the process where IT value is created from interactions of those determinants. To answer the research question, agent-based modeling technique is used in this research to build a computational representation based on the conceptual model. Computational experimentation will be conducted based on the computational representation. Validation procedures will be applied to consolidate the validity of this model. In the end, hypotheses will be tested using computational experimentation data.

Keywords: IT value, evaluation, multilevel theory, complex adaptive systems, adaptive structuration theory, agent-based modeling.

1 INTRODUCTION

Information Technology (IT) expenditure comprises a substantial portion of any organization's investment budget. Organizations seek to understand what impacts the IT has brought (Gable, Sedera, & Chan, 2008), and, thereby, determine where potential IT investments lie (Davern & Kauffman, 2000). Furthermore, the IT artifact is advocated by Benbasat & Zmud (2003) as the center in the Information Systems (IS) discipline; improving the performance of the IT artifact remains to be an imperative goal. Thus, evaluating IT value has widespread implications for studies selecting IT value as a dependent variable (e.g. IT implementation, IT adoption, IT alignment, etc.).

The business value of IT (denoted as IT value across this paper) has been difficult to quantify, partly because of the intangible nature of many of the derived benefits (e.g. improved customer service). Scholars "have adopted diverse conceptual, theoretical, and analytic approaches and employed various empirical methodologies at multiple levels of analysis" (Melville, Kraemer, & Gurbaxani, 2004, pp. 285), such as performance measures (Kohli & Devaraj, 2003), and measures that capture competitive advantages from a resource-based view perspective (Melville et al., 2004).

Much of those efforts have been valuable; however, there is yet much disagreement on how best to measure IT value. Various areas of contention and discord have been considered, such as incomplete or inappropriate measures (DeLone & McLean, 1992), lack of theoretical grounding (Gable et al., 2008) and the difficulty of isolating the contribution of the IT from other contributors to the value (DeLone & McLean, 1992).

Given ongoing difficulties for measuring IT value directly, research interests have shifted to seeking surrogates for IT value. For example, DeLone & McLean (1992; 2003) comprehensively reviewed previous studies and classified measures from those studies into six categories: system quality, information quality, use, user satisfaction, individual impact, and organizational impact (later, they updated the original model and included a new category of service quality). They argued that those categories are interrelated, and when evaluating the IT value, appropriate measures according to different organizational contingencies should be selected. DeLone & McLean's IS success model has been partially validated by several authors (Rai, Lang, & Welker, 2002; Seddon, 1997). However, their model is criticized for lacking clarity (Seddon, 1997), and insufficient theoretical and epistemological explanations (Gable et al., 2008).

Apart from the fact that there is much effort seeking surrogates of IT value, the linkage between IT value and its surrogates is relatively understudied. The question of how its surrogates contribute to IT value remains elusive. For example, user satisfaction is sometimes used as a surrogate for IT value (Bailey & Pearson, 1983). How and why satisfied users will perform better has been rarely addressed.

Regarding the question of how, the internal and external organizational environment is hypothesized to have a strong influence on IT value (Dedrick, Gurbaxani, & Kraemer, 2003; Love & Irani, 2004; Melville et al., 2004; Rai, Patnayakuni, & Patnayakuni, 1997). This suggests different value creation mechanisms related to the question of how IT value surrogates contribute to IT value, is important.

For example, IT value can be affected by management processes and IT strategy links of organizations (Rai et al., 1997), or can be created by organizational change (Dedrick et al., 2003), gaining intangible resources (Melville et al., 2004), and awareness of strategic vision (Love & Irani, 2004). Understanding those mechanisms are important for us to faithfully hypothesize the linkages between IT value surrogates and IT value, and in turn, to use appropriate IT value surrogates.

Understanding the linkage between surrogates and IT value is related to investigating IT value from a multilevel perspective. There is a divide in the level of analysis in the IT value studies; most studies were either concerned with the individual level of analysis or the organizational level of analysis (Chan, 2000; Petter, DeLone, & McLean, 2008). However, IT value is naturally a multilevel phenomenon. Those surrogates of IT value are found across multiple organizational levels. For

example, user satisfaction is evaluated at the individual level of analysis, whereas financial measures are at the organizational level of analysis.

1.1 Research Questions

In this paper, I propose a research that seeks to uncover the mechanisms of how the surrogates of IT value are linked to IT value, by decomposing IT value creation process and understanding IT value from a multilevel, complex, and adaptive system perspective. Particularly, this paper advocates for usefulness of three theoretical perspectives. It explores how those theoretical perspectives can be integrated and how they can facilitate understanding of IT value.

Specifically, those theoretical perspectives are useful lenses for explicating two research questions.

- What is the impact on IT value in the value creation process, where multiple factors interact with each other? Many factors that affect IT value have been studied in isolation, such as user satisfaction and system usage. How they interact and what are the interacting effects on IT value have been rarely addressed.
- How lower-level factors emerge at a higher-level, and subsequently, contribute to IT value? For example, system usage exists at several organizational levels (e.g. individual use and collective use) (Burton-Jones & Gallivan, 2007; Burton-Jones & Straub, 2006). How individual system usage emerges at the organizational level, and affects the organizational IT value is unclear. The cross-level emergent processes are particularly important because they can explicate how internal and external organizational processes shape the creation of IT value, and further inform management decisions for selecting appropriate measures according to organizational contingencies.

1.2 Summary of Research

This paper first introduces several theoretical perspectives in organizational studies. They are multilevel theory (Rousseau, 1985; Klein & Kozlowski, 2000), complex adaptive system (CAS) theory (Holland, 1995), and adaptive structuration theory (AST) (DeSanctis & Poole, 1994). It is invaluable to accommodate all three theories and to build an integrative research roadmap for the proposed research questions. All three theories are regarded as theoretical paradigms in this paper. Each of them provides distinct theoretical strengths in characterizing some aspects of the phenomena. They jointly leverage analytic capability to understand IT value creation process.

Specifically, AST provides a process-oriented paradigm for us to understand the value creation process. It is particularly useful to collect relevant concepts and processes through the lens of analytic components defined in AST. Thus, it will be used as a tool for distilling relevant concepts and processes from existing IT value studies in the literature.

On the other hand, multilevel theory emphasizes cross-level phenomena. It is a paradigm for characterizing and understanding concepts and processes from a multilevel perspective. Thus, it serves as a theory-generation machine that frames cross-level theories from existing single level concepts and processes. For example, multilevel theory explains emergent processes with structures and functions (Morgeson & Hofman, 1999), and classifies them according to their structures and functions (Chan, 1998).

CAS theory focuses on the dynamic adaptive process, where the dynamics of IT value creation can be characterized by systems components in CAS. The cross-level theories regarding the proposed research questions can be described in CAS terms, through a mapping process. In addition, CAS description can be easily operationalized as formal models, which permits simulation in a computational environment.

This research uses agent-based modeling technique to operationalize conceptual model into executable computer programs, and to recreate a virtual environment that mimics the reality of IT value creation. In this virtual environment, research questions are explored by running computer simulations, which is

analogous to experimentation. This experimentation will examine the dynamic IT value creation process, and probe the effects of various interacting factors in this process.

This research then follows established procedures to validate the proposed computational model through grounding and verification. Empirical case studies data will be collected from the literature and be used to validate the proposed model.

1.3 Expected Contribution

First, the proposed research will empirically investigate the question of “how” regarding linkages between the surrogates and the IT value. While the linkages are often measured and assumed, it is surprising that how the surrogates or the determinants of the IT value contribute to the IT value is relatively understudied. Thus the proposed research can contribute to understanding the question of “how”.

Second, the proposed research will contribute to providing a precise description of the IT value creation process, in comparison with previous studies. Constrained by the methodological limitations of variance analysis approach, many studies were only able to investigate linear relationships among the determinants or limited patterns of nonlinear relationships, even through introducing exponents and logarithms (Anderson, 1999). Interpretive case studies, however, were constrained by “precision”, where verbal propositions and conclusions might introduce ambiguity (Nan, 2011). This research is in an intermediate position where it can precisely describe the interacting dynamics of surrogates or determinants of the IT value in the value creation process.

Third, the proposed research can enrich cross-level studies of IT value and demonstrate one way to integrate existing studies at different levels. Most IT value research was either at an individual level or at an organizational level. Single level study only provides a disjointed view of phenomenon (Burton-Jones & Gallivan, 2007). Thus this research can help gain a better understanding of IT value from a multilevel perspective.

Fourth, the proposed research will make a methodological contribution. Agent-based modeling is used in this research. Although this research is not the first to apply agent-based modeling, it will enrich the application of the approach in the behavioral and psychological domains of the IS discipline, considering the relatively low volume of application.

Lastly, the proposed research can aid management decisions pertaining to IT policies. The proposed model can be used to predict possible outcomes and risks of IT value by experimenting various IT policies in the computational simulation. The simulation results are valuable insights to visualize what could happen; thus minimizing potential risks for decision-makings.

2 THEORETICAL FOUNDATION

This research embraces a multilevel, complex, and adaptive system view to understand IT value. The ontological and epistemological conceptions of this view are crucial for understanding the ideology of this research. This section illustrates those conceptions.

2.1 Multilevel Theory

Organizations can be conceptualized and analyzed from multiple organizational levels, such as individual level, group level, department level, and organizational level (Kozlowski & Klein, 2000). Many organizational studies were only concerned with a single level. They can be roughly divided into two camps - micro level studies and macro level studies. The two camps often have distinctive perspectives and epistemological groundings, where micro level studies emphasize psychological process and macro level studies emphasize organizational properties such as growth and change (House, Rousseau, & Thomas-Hunt, 1995).

These two paradigms, from micro and macro perspectives, can often be complementary to each other (Rousseau, 1985) due to their ontological and epistemological conceptions. It is argued that organizational phenomena are multilevel in nature – existing at ‘both’ macro and micro levels (Chan, 1998; House et al., 1995; Klein & Kozlowski, 2000; Klein, Dansereau, & Hall, 1994; Kozlowski & Klein, 2000; Morgeson & Hofmann, 1999; Rousseau, 1985). As phenomena are common at different levels or across levels, investigating one level, while ignoring similar phenomena at another level, can result in incomplete theories (House et al., 1995).

The multilevel theory views advocates for identifying principles or laws that enable a more integrated understanding of phenomena that unfold across levels in organizations (Kozlowski & Klein, 2000) (Kozlowski & Klein, 2000). In this regard, by adopting a multilevel perspective, one can avoid the commonly existing problem of examining organizational phenomena only at a single level at any given time or study, as it provides an unnatural, incomplete, and very disjointed view of how organizations function (Burton-Jones & Gallivan, 2007).

2.2 Complex Adaptive Systems Theory

Complex Adaptive Systems (CAS) (Holland, 1995) theory assumes there were some similar systems representing complex patterns through even some basic interactions. For example, the goods trading market always maintains dynamic balance while buyers and producers only follow some basic rules to behave. There are no central coordination systems in the market. The question is how the dynamic balance is kept in this complex system? CAS is developed to deal with such questions.

One fundamental characteristic for those systems is complexity, or in other words, nonlinearity - the whole is more than the sum of its parts (Holland, 1995). Because of nonlinearity, the complexity emerges from simple interaction; the whole cannot be decomposed into its parts to analyze.

CAS is fundamentally an analytic theory (Gregor, 2006), which have two basic analytic elements – agents and environment (Holland, 1995), as illustrated in Table 1. First of all, CAS can be viewed as “systems composed of interacting agents described in terms of rules” (Holland, 1995, pp. 10). Agents or artificial agents, such as organisms, individuals, companies, or countries, are the basic analytic units with inherent attributes and behaviors. They are constrained by a set of behavioral rules, which decide how they will act when interacting with other agents and the environment. In CAS theory, agents will try to survive through adapting the environment (Holland, 1995). This process is called adaptation.

Elements	Meaning	Example
Agents	Analytic units with inherent attributes and behaviors.	Individuals, companies, etc.
- Attributes	Properties of the analytic units that are common to all instances.	Gender, weight, etc.
- Behavioral rules	Rules that shape the exact actions of analytic units.	Employees prefer high-compensation jobs.
Environment	The context where agents reside and interact with each other.	Organization, forest, society, etc.
- Attributes	Properties of the contexts that are the same kind.	Number of trees in a forest, density of society, etc.
- Environmental rules	Rules that characterizes the changing patterns of the environment.	The number of trees will increase 10% every year.
- Network structures	Mediums that connect agents to interact.	Social connections.

Table 1. Summary of basic analytic elements in CAS theory.

The environment is another basic element in CAS as the environment provides the context where agents reside and interact with each other. Agents with more adaptive capabilities will thrive while agents with less adaptive capabilities will decay. Environment also has its attributes, environmental

rules, and network structures. Attributes and environmental rules specify the properties and changing patterns of the environment. For example, the number of trees in a forest might increase 10% on average every year. Network structures provide mediums or platforms for agents to interact. For example, agents were only able to interact with their social ties.

2.3 Adaptive Structuration Theory

The *Adaptive Structuration Theory* (AST) (DeSanctis & Poole, 1994) has been proposed to study the role of technologies in the organizational change process, in the Group Decision Support System (GDSS) setting. Major constructs and propositions of AST are illustrated in Figure 2. Although studied in GDSS context, DeSanctis & Poole (1994) argued that the theory is generalizable to other research contexts for investigating a variety of technologies and organizational outcomes, such as IT value. In this theory, they used Gidden's structuration theory to explain organizational change resulting from IT. One important extension is that they conceptualize IT as two structures. According to existing theory on the duality of technology, there is a continuous interplay between the technical and social sides of IT, where IT is physically constructed by actors working in the physical environment and socially constructed through the interactions of actors in the social environment (Orlikowski, 1992). Thus, IT is conceptualized as consisting of both structural features and spirit. The focus of AST is social structures and interactions among different elements or constructs. The strength of AST is the process-oriented nature, which explains that organizational change is resulted from social interaction process involving IT and other structures.

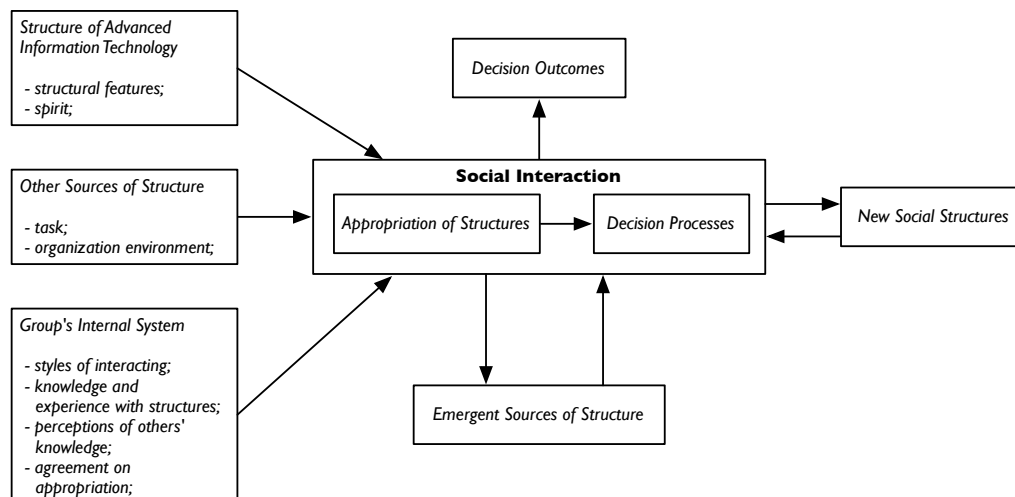


Figure 2. Major constructs and propositions in AST (adapted from DeSanctis & Poole, 1994).

3 METHODOLOGY AND RESEARCH DESIGN

The method in this research is called *Agent-Based Modeling* (ABM) (Bonabeau, 2002). Agent-based models are formal or computational models, which are a set of computer programs. It is theoretically based in *Complex Adaptive Systems* (Holland, 1995), which conceptualizes basic analytic units of agent-based models, such as agents, attributes of agents, interactions, behavioral rules, networks, etc. Theoretical constructs need to be “translated” into computational representation. This process is analogous to operationalization of theoretical constructs into items when using survey method. For example, firms are modeled by agents; and processes and activities are reflected in behavioral rules of agents and interaction patterns among agents. The operationalization is often a mapping between the conceptual model and elements in agent-based models. By taking advantage of computing power, the interactions among agents and of agents with their environment were recreated in a virtual environment by step-by-step iterations of agents’ movements.

Using ABM has several benefits: (1) the ability to capture emergent phenomena in a complex system, (2) the ability to provide a natural and intuitive description of the phenomena, and (3) the flexibility to control variables in the computational experiments (Bonabeau, 2002).

Because of the difficulties to model the nonlinear outcomes of many interacting variables, simple causal models are not enough to model complex interconnections (Anderson, 1999). However, ABM does not seek to build a direct mathematical model to relate independent and dependent variables. What it models is the activities that were actually happening in the real world. Consequently, complexities will not be reduced and they can emerge through simulation. Furthermore, it is natural and intuitive because it is actually describing the real-world entities rather than conjecturing some variables for the convenience of research (Bonabeau, 2002). In addition, the most significant advantage might be the flexibility to control variables in a computational experiment. Because the computational experiment requires relatively less resources and time than human experiment, the ABM can be easily modified and re-experimented over and over again with little additional burden for researchers. This ideal controllability of ABM is sometimes unreachable or extremely expensive for real-world experiments. For example, if we want to examine the possible outcomes of different policies in controlling a financial crisis, it is unlikely we can recreate a financial crisis in a real-world experiment.

Roughly, the proposed research follows a four-stage research design. The first stage will ground the proposed conceptual model on concepts and processes in the literature through the lens of AST. The second stage will build the conceptual model with those identified concepts and processes, following the CAS analytic framework. The third stage is to create the computational representation with ABM. The last stage will validate the computational representation and conduct experimentation.

3.1 AST as a Paradigm to Collect Concepts and Processes

The original concepts and propositions in AST were concerned with GDSS in small group settings; however, those concepts and propositions are generally appropriate for other research contexts (DeSanctis & Poole, 1994). Thus, AST will be used as a lens to collect concepts and processes in the IT value literature. For example, concepts such as structure of IT, structural features, spirit, internal system, social interaction etc. in the AST can be operationalized as coding schemes to identify contextualized concepts that are relevant to IT value studies, such as user satisfaction, system quality, information quality, competitive advantage, etc. The result of this stage is a repository of concepts and processes regarding IT value.

3.2 Building CAS Model with IT Value Concepts and Processes

The identified concepts and processes will be linked from a multilevel perspective; namely, they will collectively reflect the emergent IT value creation process. Those concepts and processes from the multilevel perspective will be tagged as the conceptual model in this research. The conceptual model then will be described with CAS terms through a conceptual mapping process. The result of this stage is a mapped CAS conceptual model.

3.3 ABM of the Conceptual Model

The conceptual model will be operationalized into computational representation, using ABM technique. An open source software platform, *Repast* (available online at <http://repast.sourceforge.net>), is readily available to implement the full features of ABM and to conduct computational experimentation. The platform also contains a variety of tools for observing data dynamics and manipulating model parameters through an interactive interface. Detailed operationalization process includes operationalization of theoretical constructs, substantiating constant variables in underlying assumptions, developing algorithms to reflect the logics of the conceptual model, etc. The result of this stage is a computational representation of the conceptual model.

3.4 Validation and Experimental Simulation

Lastly, the computational representation needs to be validated before computational experimentation. Validating computational models can be extremely complex; various types of validity can be validated by different techniques. The most important and commonly evaluated is external validity, referring to “the adequacy and accuracy of the computational model in matching real world” (Carley 1996, pp. 2). Unlike common variance models, computational models are not either valid or not valid; however, they have a degree of validity (Law & Kelton, 1991). Specifically, from lower level to higher level, eight sub-types of external validity can be distinguished: face validity, parameter validity, process validity, pattern validity, point validity, distributional validity, value validity, and theoretical validity (Carley, 1996). In this research, validation of external validity will use two general approaches of grounding and verification recommended by (Carley, 1996), to validate face, parameter, process, and pattern validity. Because the purpose of the model in this research is for understanding instead of predicting for specific conditions, it is generally appreciated that higher-level validity, such as point validity, is not required (Burton & Obel, 1995).

Grounding involves techniques such as story telling, initialization, and simple evaluation of patterns (Carley, 1996). The goals of grounding are often to evaluate the face validity – computational model has the appearance that looks like reality, parameter validity – parameters of computational model match with real world data, and process validity – the processes described by the computational model match with real world processes. The core of grounding is to justify the input of the model is similar or the same as the real world.

Verification involves comparing the artificial data generated by the computational model with real world data. The comparison is often achieved graphically or statistically (Carley, 1996). It can validate the model’s pattern validity, defined as “the pattern of results generated by the computational model matches real patterns of results” (pp. 10). The real world data is collected by coding qualitative studies or qualitative part of quantitative studies, related to IT value. It is unlikely all propositions in the model can be validated in a single qualitative study. However, multiple qualitative studies can jointly validate the proposed model.

Validated model will be readily available for experimentation, in order to investigate the research questions. Through continuous improvement in previous steps, the proposed a priori research questions will be further articulated and be operationalized suitably for experimentation. For example, it is suggested in AST, “four major sources of structure (technology, task, environment, and the group’s internal system) affect social interaction which, in turn, is the key determinant of social outcomes” (DeSantics & Poole, 1994, pp. 144). The experimentation can test those hypotheses using collected artificial data generated in the simulation process. Specifically, it can examine the questions such as (i) do those sources of structure (i.e., determinants of IT value when mapped in the AST framework) affect social interaction and eventually affect the organizational level IT value? And (ii) if so, how do they affect the organizational level IT value? What are the interacting effects of them on IT value?

In addition, internal and external environmental factors can be similarly examined to probe the social and organizational influences on the IT value creation process. For example, it is useful to ask which internal and external environmental factors have the strongest impact on this process, and which have the weakest impact. In summary, once the simulation platform is created and validated, various effects of the emergent process can be investigated.

4 PROGRESS TO DATE

The current PhD candidate was in the process of refining the research design. Agent-based model might be procedurally easy to build, but conceptually difficult to understand. It is hoped this research can be refined to produce a feasible and more valid research design.

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